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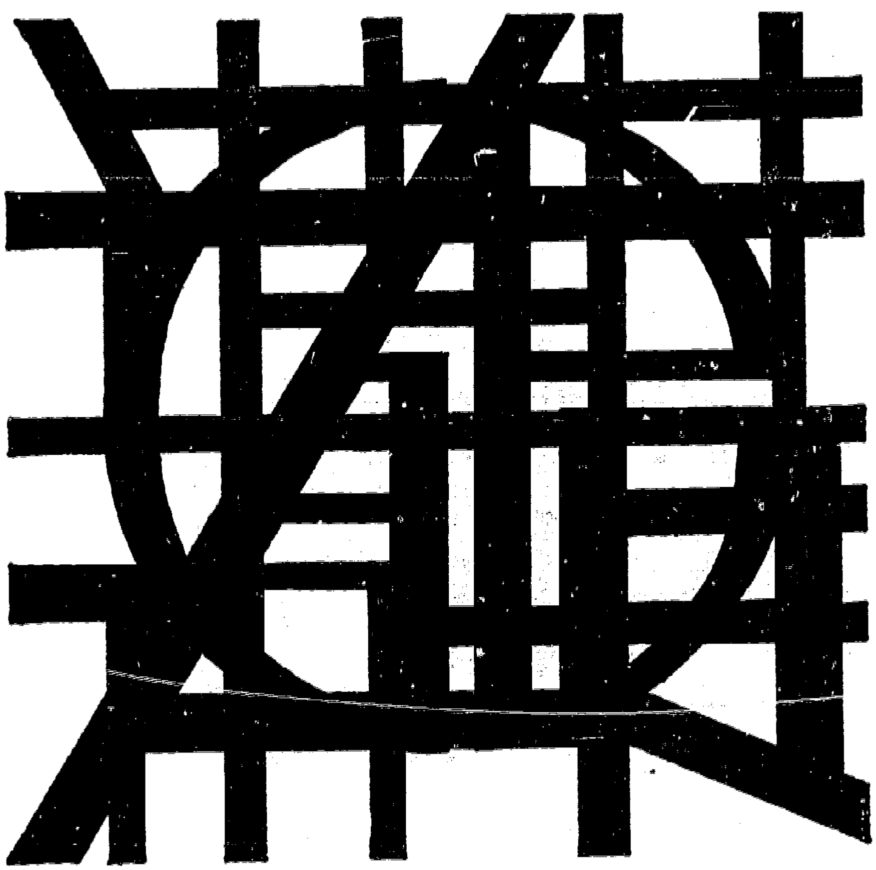
ABSTRACT

This bulletin contains three articles which focus on ground water's potential as a dependable supply source and some of the problems impeding the development of that potential. The authors' concerns are discussed from the vantage point of their areas of specialization: law, sociology, and economics. The first author states that water law abounds with unanswered questions and administrative efforts to isolate water's use for public consumption from its many other uses are equally arbitrary. In the sociological area, there seems to be a failure on the part of all citizens to understand water supply and pollution issues. The economist estimates that available ground water resources might be able to satisfy projected water supply needs in Rhode Island at costs significantly lower than those associated with surface reservoirs. (Author/CP)

CONCERNS IN WATER SUPPLY AND POLLUTION CONTROL: LEGAL, SOCIAL, AND ECONOMIC



Bulletin Number 1
University of Rhode Island
Community Planning and Area Development

CONCERNS IN WATER SUPPLY AND POLLUTION CONTROL: LEGAL, SOCIAL, AND ECONOMIC

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INTRODUCTION

Rhode Island is presently planning for new sources of water for domestic and industrial use. One estimate indicates that before the year 1980, the state's residents will require 50 percent more water than they now use.[1]

In the past, surface water development has out-paced the development of ground water supplies. Currently, the state has developed from all surface and ground water sources, a dependable supply of 147 mgd (million gallons per day). Of this amount, only 15 mgd has been developed from ground water sources. That part of the total supply in industrial use totaled 75 mgd, with 13 mgd of this coming from ground water sources. Plans for future development advocated by the State Water Resources Board and the Providence Water Board indicate that surface water supplies will continue to be developed. Yet, mounting evidence suggests that the development of ground water supplies offers a more feasible alternative.

Each of the articles which follow focuses on ground water's potential as a dependable supply source and on some of the problems impeding the development of that potential. The authors' concerns are discussed from the vantage point of their areas of specialization—law, sociology and economics.

Since water quality considerations rank among the most important in developing supplies for public use, Professor Burke's survey of Rhode Island law and administrative practices relating to ground water pollution provides an appropriate beginning. Water law, according to Burke, abounds with unanswered questions. Perhaps because of this, water law also has considerable promise as a means of formalizing effective ground water conservation and use policies. In order to serve this function, however, the law should recognize, as hydrological evidence indicates, that all water on the planet is a part of the same hydrological system. A stream is merely a cut in the water table of an area; today's rainfall is tomorrow's stream or river. Legal distinctions separating ground water, surface water and percolating water have no basis in fact. Burke's paper also indicates that administrative efforts to isolate water's use for public consumption from its many other uses is equally arbitrary.

Professor Spaulding, in his article, presents a second problem area which has implications for water resource policies and development activities. According to his findings, there seems to be a failure on the part

1. Rhode Island Development Council. A Water Resources Program for Rhode Island (Providence: Water Resources Memo No. 3, Rhode Island Development Council, Planning Division, 1954), pp. 209. Data presented in paragraph one above was found in this source.

of all citizens—no matter what their income, education or background—to understand water supply and pollution issues. This appears to be especially true in regard to ground water. The notion prevails that "if it can't be seen, it doesn't exist." The lack of public understanding of water issues may well make it more difficult to marshal the public support required to bring about changes in traditional water resource policies. Water resource decisions affect every citizen. Yet, without some fundamental understanding of water resources, policy-making becomes increasingly the sole concern of technocrats and small interest groups.[2]

The issues raised by these first two articles become even more significant when viewed in the context of the third, by Professor Jeffrey. Using dollars and cents estimates, Dr. Jeffrey compares the cost of the Big River reservoir complex, now advocated by the State Water Resources Board, to the cost of protecting and developing ground water supplies located in the same general area and yielding approximately the same quantity of water. According to his analysis, available ground water resources might be able to satisfy projected water supply needs in Rhode Island at costs significantly lower than those associated with surface reservoirs. In addition, Dr. Jeffrey's analysis shows that, when the costs of pollution control are included, the difference in costs of the two sources is enough to offset the cost of pollution control in the area studied.

These three articles clearly indicate on the one hand the potential benefits of ground water development, and on the other hand suggest some of the difficulties impeding efficient ground water utilization in the state. The message is unmistakable: Rhode Island is blessed with an abundant ground water resource which few people know about, the water supply is inadequately protected by law, and can be developed at a relatively low cost to provide a dependable water supply to meet future demands.

2. Indicative of this trend is legislation introduced by the State Water Resources Board which, if adopted, would permit that agency to issue revenue bonds—not subject to legislative or voter approval—to finance acquisition and construction costs related to future reservoir development. Such a grant of authority would remove water development issues still further from public view and control. See: Robert C. Frederiksen, "Water Resources Body Denies Aim to Bypass Voters," Providence Journal, April 14, 1970.

LAW AND ADMINISTRATION

D. Barlow Burke, Jr.[1]

This paper will do three things. First, the body of law governing percolating ground water in Rhode Island will be reviewed. Second, the administrative and enforcement practices regarding underground water pollution in the state will be presented. Finally some recommendations for improving anti-pollution procedures will be made.

SURVEY OF LAW RE GROUND WATER POLLUTION

Case of Common Law. According to the "English" rule of common law, a landowner has an absolute right to appropriate any water seeping under his land.[2] Unlike the riparian doctrine, applied to the use of surface and subterranean streams, the appropriator of percolating waters under this rule has no responsibility to share his supply with his neighbor. His right to the water is absolute.

This rule of absolute ownership was modified in some American jurisdictions during the 19th century, usually by separating the right to appropriate from the right to pollute. American courts have said that the person appropriating percolating waters must make "reasonable use" of them, and this meant not polluting his neighbor's otherwise pure supply. The appropriator must take account of the "correlative rights" of his neighbor. Violators of these rights are liable for the damage caused.

However, courts are still divided concerning the standards to be applied in deciding issues of this kind. Specifically, must the plaintiff prove that the polluter-defendant both caused the damages claimed and that the defendant could have foreseen (and therefore prevented) the damage his actions caused, or is it simply enough for the plaintiff to prove that his rights were damaged by the defendant's actions? Of course, it is often easier for the plaintiff to prove his rights damaged by a "nuisance" resulting from the actions of the defendant than to prove "negligence"—that the defendant acted knowing full well that damage to the plaintiff would result.

Rhode Island courts have dealt with this issue in two major cases — Rose v. Socony-Vacuum Corporation[3] and Gagnon v. Landry[4]. While the results of these cases are mixed, they do make possible certain conclusions concerning the courts' position regarding ground water pollu-

1. Assistant Professor of Planning Law, University of Rhode Island.
2. In this, and in all that follows, one must distinguish percolating waters—those seeping underground not in a defined channel or watercourse—from subterranean streams. Doctrines of riparian rights have long defined the rights of owners in subterranean water-courses, but similar legal rules took longer to develop in the case of percolating waters.
3. 54 R. I. 411, 173 A. 627-630, (1934). Appeals related to Rose found in 56 R. I. 272, 185 A. 251 (1936) and 56 R. I. 472, 188 A. 71 (1936) (per curiam opinion).
4. R. I. 234 A. 2d 674-677 (1967).

tion. First, it is clear that the "English" rule has been modified to allow consideration of such questions as the purposes to which the parties at bar use the land involved.

For example, in "Rose" the court indicated that the first issue to be decided is whether the "social purpose" of the defendant's land use is such that it should receive judicial protection. If the defendant's land use is found to have a legitimate social purpose, apparently the plaintiff must prove negligence in order to collect damages. Simply to prove the existence and cause of a nuisance is not sufficient to collect compensation for damages.

Secondly, it is clear from Gagnon v. Landry that the State Health Department controls septic tank pollution in some way and that its determinations may be applied by the court in deciding questions of this nature. Septic tanks or other polluting devices must be repaired with reasonable promptness, or liability of the owner will result in order to prevent "continuing pollution" (see "Gagnon") of percolating waters.

However, these decisions leave many questions unanswered and raise others. For example, in "Rose" the court stated that the right of ownership of percolating waters was "relative," but it is not clear what this implies—how is a relative right defined? Further, in the "Gagnon" decision, upholding the trial judge's determinations, did the court merely mean that the judge ruled correctly, or was it also implied that he formulated the issues of the case correctly? If the latter was intended, then a case involving the pollution of percolating waters must be decided on three counts: (1) was there a negligent appropriation of percolating waters? (2) did the later pollution constitute a nuisance? and (3) what is the danger of continuing pollution?

Other unanswered questions include: What happens if an area is overdeveloped so that on site treatment of sewage is ineffective and the ground water becomes polluted? What if ground water is the only source of water supply for such an area? Can a sewage system or a public water system be required? Who pays in either case? Can future building be enjoined if this situation is imminent?

This is only to suggest that the case law of Rhode Island offers several possibilities for increasing the penalties for the pollution of percolating waters. Both "Rose" and "Gagnon" were decided loosely enough to make judicial protection of the polluter less certain. Other avenues of proof remain as well. Use of statutory standards in both federal and state laws for defining the polluter's duty to other landholders in private lawsuits is one unexplored approach.

Courts must also be willing to do what the administrative process is now trying to do—that is, to devise effective remedies for cases of

"continuing pollution." In such cases, the court must grant damages as well as some type of injunction, which if violated would result in automatic penalties to the polluter.

The courts should also consider "conditional decrees" such as that imposed by a court in Delaware.[5] Such decrees might recognize both the rights of the polluter to use percolating waters on his property and those of the plaintiff to unpolluted waters on his property and apportion the costs required to satisfy both rights—perhaps the cost of digging a deeper well or of installing an improved pollution abatement system—equitably among the parties involved.

Statute Law. Administration and enforcement of state statutes relating to ground water pollution have been delegated primarily to the State Department of Health. This agency has general authority to prohibit activities which threaten the quality of public water supplies and to initiate prosecution of those who violate orders of the Director of Public Health.

While the bulk of the department's responsibility focuses on public supplies, the 1968 legislature did adopt legislation which requires a minimum distance of 100 feet between a sewage unit and any kind of well—public or private.[6] This legislation was designed to prevent the pollution of water supplies due to inadequate sewage facilities, particularly septic tanks, located in areas not serviced by public water or sewer systems.

Thus, the statutes authorize the Department of Health to act in three areas: to survey, sample and, if necessary, order improvements in public supplies and to approve any new sources of supply for public use; to enforce the law requiring at least 100 feet between any water supply and sewage facility; and to test private water supplies either on request or as part of its responsibility to enforce water quality standards.

ADMINISTRATIVE AND ENFORCEMENT PRACTICES[7]

Introduction. Primary responsibility for enforcing water pollution laws has been delegated to the Department of Health and particularly to the Division of Water Supply and Pollution Control. The administrative chain-of-command is depicted on the following chart.

5. See: McCartor v. Graylyn Crest III Swim Club, 173 A. 2d 344 (Delaware Court of Chancery, 1961).
6. R.I. General Laws (1956), 1969 supplement, S 23-1.
7. Field work and interviews for this section were conducted by Mr. Henry Skoburn and Miss Margaret Concannon, graduate assistants in Planning and Area Development Curriculum, University of Rhode Island. The author thanks them; their frustrations in dealing with state officials provided me with many clues to the inefficiencies of the system.

Director of Public Health

Assistant Director for Environmental Health Services

Director of Water Supply and Pollution Control

Water Supply Control Section — Water Pollution Section

Water Supply Control Section. Division personnel currently spend up to 80 percent of their time collecting samples of public water supplies at their source. Supply facilities of public institutions and industrial plants, as well as schools, military facilities and public swimming pools and beaches are inspected. In addition, division personnel inspect private wells which are being considered for hookup to public systems. Such supplies must be approved by the Department of Health before the connection can be effected.

However, the department, at the present time, is not fully exercising its powers over private wells, resulting from 1968 legislation requiring 100 feet between a sewage unit and any type of well. While the department does not test private wells on its own initiative, it does provide assistance to interested parties when requested, and it also analyzes samples submitted by private well owners. About 1200 private wells were tested in fiscal year 1967-1968, and 1500 were tested the following year.

In addition, complaints received by the department—usually concerning discoloration, taste and odor in public wells—are acted on by this section. However, records are not kept on these complaints nor is the action taken recorded where department administrators feel certain nothing is wrong with the supply. In most cases the cause of the complaint can be readily eliminated by the appropriate supply agency or company at the local level.

Water Pollution Control Section. This section is responsible for general supervision of sewage facilities, for investigating complaints and for conducting special investigations and surveys of pollution sources. Complaints received each year vary according to area. In fiscal 1968-1969, miscellaneous special investigations numbered 375 and 179 pollution surveys were conducted.

The activities of this section focus on public sewage systems. As of 1967, 68 percent of the population was served by sewers and provided treatment; 1 percent was served by sewers but not provided treatment (Jamestown and North Smithfield systems discharge untreated effluent directly into Narragansett Bay); and 31 percent was served by individual septic tanks and cesspools.

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Enforcement. The primary tool for preventing pollution is pre-construction inspection and review of plans, specifications and sites of public supply and pollution control facilities. Enforcement after the fact is difficult. No records are kept by the Department of Health as to the number of hearings held annually and records are not kept on those cases where action might be taken. There have not been any court cases brought by the department during the past year (one action was ended when the defendant moved outside the state's jurisdiction just prior to the court's hearing of the case).

Enforcement is difficult for four principal reasons. First, in Rhode Island each department has a legal counsel, a political appointee, who changes with each new governor. These lawyers are seldom knowledgeable on public health problems. They also continue in private practice and thus devote only some of their time to departmental work.

Secondly, time works against enforcement—a great deal of time is required to prepare a case against a polluter. In the case that was almost brought to court last year, the alleged polluter moved into Massachusetts before legal action could be taken, although the department had proof that large amounts of manure deposited on the land was causing pollution in waters of Rhode Island.

Moreover, because of lack of staff and supporting funds, it is extremely difficult to police the whole state and to compile the material necessary to prove that violations have occurred. If a person complies with state standards in constructing sewage disposal units and pollution still occurs, the department is not likely to prosecute. If a builder obtains a building permit from a town official and then builds a well and sewer without first obtaining departmental approval, the courts in the past have been reluctant to act. Once either a sewer or well is built, there is no way of knowing if the individual has conformed to state standards without incurring a great deal of cost—costs that the department cannot meet.

Finally, except for the 1968 legislation requiring a minimum distance of 100 feet between sewage units and water supplies, the Department of Health does not have legal authority over private water supplies. It can make rules for private wells, but it cannot prosecute on the basis of such rules due to lack of statutory authorization. Thus, the department concerns itself with criminal cases unless drawn into civil law matters by complainants.

In addition, there is reason to believe, as some interest groups have charged, that enforcement of pollution control statutes is inadequate (and more effective statutes have not been proposed) because of the department's narrow interpretation of its responsibilities. Due to its public health orientation, the department is concerned primarily

with water quality in public systems, not with the quality of all waters throughout the state. Unless there are large amounts of raw sewage, there is little interest in enforcement. Direct causes of disease are acted on; indirect causes, such as chemicals in rivers and the slow death of surface and ground waters from plant growth, are not.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions. This survey of case and statute law indicates that the state's courts and administrative agencies have a number of tools available for dealing with the problem of pollution, but many of these tools have not yet been used. The courts, by moving away from the "English" rule have opened the door to such considerations as land use, correlative rights of landowners and conditional decrees designed to resolve the immediate dispute and to protect against continuing pollution.

However, courts only become involved when a dispute is brought to their attention and enforcement of their decrees depends largely on the state's administrative agencies, specifically the Department of Health. Unfortunately, the department's role is restricted by two general limitations. First, the bulk of its authority and activities are concentrated on public water supply systems. This concentration continues despite the increased development of new private supplies and sewage systems in previously open areas. Generally, the department becomes concerned with private supplies only at the request of the well owner—and he, in turn, requests departmental assistance only when he has reason to believe that his supply is contaminated.

Furthermore, even when private supplies are analyzed, the results are usually presented as raw scientific data which the layman must interpret for himself. Records of such analyses are not kept on a systematic basis by the department and in most cases when contamination is indicated, the department fails to trace the contamination to its source.

A second, related limitation results from the Department of Health's (and the statutes') narrow interpretation of water use. The ineffectiveness of Rhode Island's laws in this field can be traced, in part, to the presumption that the only important concern which humans should have with water arises when they drink it. But water has many other uses—recreational, industrial, agricultural and ecological. These other uses are also important to public health and well-being, but their importance is not recognized by statute or administrative practice.

Further, this limitation does not recognize that ground water pollution may occur incrementally over a span of time. Over-development, poor design and construction and other activities may occur which may

not result immediately in the contamination of public supplies, but which may irreversibly begin the process.

Recommendations. All of the foregoing implies that some changes in the present law are in order. First, the Department of Health should adopt, in addition to its five-tier system of water quality standards, a base-line standard providing a minimum quality measure for all waters in the state. This base-line standard should be published and made available for public reference.

Secondly, the department should be required to keep complete records of all its tests and the results should be available, and by statute useable, as standards governing private law suits against polluters. In addition, the department should interpret its own data in a way meaningful to interested laymen. It is not enough to provide laboratory analyses in technical terms and expect the general public to interpret them accurately.

Third, the Department of Health should assert its responsibility not simply to protect public water supplies, but to protect the quality of all waters in the state. It should actively seek any additional statutory authority required to perform this function. Further, it should compile and analyze data on water quality in order to develop future policies designed to prevent new sources of pollution and to eliminate or abate existing sources.

Finally, in view of the department's limited budget and manpower, perhaps the most effective way to improve enforcement of anti-pollution laws is to facilitate proceedings brought by private citizens. Citizens might function as private attorneys-general and be given the right to invoke and enforce department laws and regulations in their own actions against polluters. In such actions, the department should be required to supply base-line quality standards for the ground water involved.

These standards would specify norms for the efficient functioning of the local hydro-ecological system and, below the levels set, compensatory and injunctive remedies should be provided. Where feasible, the state should perform and pay for the required tests.

In order to institute this system, data from state-wide surveys should be collected. Such procedures are not panaceas, but they are clearly needed for the protection of one of our state's basic resources.

PUBLIC KNOWLEDGE OF WATER POLLUTION AND SUPPLY

Irving A. Spaulding[1]

The solution of water pollution and supply problems depends only in part on the bureaucracy of governmental agencies and of industry and commerce; it also depends in part on the action of people in their local communities. Solution is best accomplished when people have motivation to do the job and have the knowledge necessary to analyze a problem and formulate a solution for it.

Water resource problems appear to arouse people's emotions, but there is question about the degree of their concern in the areas of water pollution and supply and about the extent to which they are accurately informed in these areas. Information about people's concern and knowledge with respect to water pollution and supply can help clarify some of the human aspects of water resource problems; it can be of use in planning courses of action—including educational activity, should it be deemed necessary—for their solution, with participation of both wide-ranging bureaucracies and local communities.

METHOD OF STUDY

Since a priori it could be assumed that knowledge about the environment would be correlated with socio-economic status, household heads of three social status groups were compared with respect to their general knowledge about pollution and supply of ground water and of surface water. The hypothesis being tested was that more knowledge would be associated with high status and less knowledge would be associated with low status.

Questionnaires were sent in July, 1969, to household heads in a sample of single household dwelling units served by one water system in the city of Warwick, Rhode Island; the sample was 3460 dwelling units. A return of 11.07 percent was secured; hence, 383 questionnaires were returned and analyzed.

Social Status of Household Heads. A social status index was devised by use of information on current house value, household income, education of the household head, and occupation of the household head. Each variable was divided into three sections which were weighted 1, 2, and 3, with 1 representing the lowest contribution to status and 3 representing the highest contribution to status. For each household head, weights for these variables were averaged; multiplied by 100, this average became an index which made possible the grouping of the respondents in broad status categories, or groups. Respondents were distributed as follows:

1. Professor of Sociology, University of Rhode Island, Kingston; the assistance of O. P. Monterecy and J. M. Bordes, graduate asssistants in Community Planning and Regional Development, is gratefully acknowledged.

Group I (high status)	300-234 interval,	87 respondents
Group II (middle status)	233-167 interval,	206 respondents
Group III (low status)	166-100 interval,	90 respondents

In sequence of decreasing status, they comprise 22.72, 53.79, and 23.49 percent of the 383 respondents examined.

Information Indices. Information indices concerning knowledge about pollution and supply of ground water and of surface water were constructed in a similar manner. In each case, the procedure was that of taking a "true-false" inventory with eight statements for ground water and eight for surface water. Each statement had been evaluated by three qualified persons as being essentially "true," "false," or "questionable."

Without knowing how statements had been evaluated, each respondent was asked to indicate whether he agreed with, was uncertain about, or disagreed with each statement. In the construction of the information indices, a respondent's evaluation was regarded as "right" if it showed agreement with a true statement, disagreement with a false statement, or uncertainty with respect to a questionable statement. Other evaluations were regarded as "wrong."

The ground water information index was constructed by subtracting the number of "wrong" evaluations pertaining to statements about ground water from the number of "right" evaluations; this difference was divided by 8, the number of statements used. The quotients had a range from +1.00 to −1.00, and any index could be converted to a position within a linear sequence of positive numbers.

In the table on page 16, an index of 20.0 represents 8 correct evaluations of 8 statements, 15.0 represents 6 correct evaluations out of 8, 10.0 represents 4 correct evaluations, and 5.0 represents 2.

The surface water information index was constructed in the same manner as was the ground water information index.

ANALYSIS OF DATA

Ground Water (Water from a Saturated Zone in the Earth). With respect to knowledge about pollution and supply of ground water, there was no statistically significant difference among the three status groups. This held both for distribution of information indices and for the mean indices for each status group. Yet, the data indicated that in all groups a majority of the respondents lacked information about ground water pollution and supply. There was a predominance of respondents (more than one-half) who evaluated less than one-half of the statements correctly. Most of them evaluated between one-fourth and one-half of the statements correctly. For all respondents, 60.3 percent of the information indices fell in this range. For status groups I, II, and III, the percentages

Interval	Information Indices	Linear Positive Sequence
1	+ 1.00 —	20.0 —
2	+ 0.90 — 0.99	19.0 — 19.9
3	+ 0.80 — 0.89	18.0 — 18.9
4	+ 0.70 — 0.79	17.0 — 17.9
5	+ 0.60 — 0.69	16.0 — 16.9
6	+ 0.50 — 0.59	15.0 — 15.9
7	+ 0.40 — 0.49	14.0 — 14.9
8	+ 0.30 — 0.39	13.0 — 13.9
9	+ 0.20 — 0.29	12.0 — 12.9
10	+ 0.10 — 0.19	11.0 — 11.9
11	+ 0.00 — 0.09	10.0 — 10.9
12	— 0.10 — 0.01	9.0 — 9.9
13	— 0.20 — 0.11	8.0 — 8.9
14	— 0.30 — 0.21	7.9 — 7.9
15	— 0.40 — 0.31	6.0 — 6.9
16	— 0.50 — 0.41	5.0 — 5.9
17	— 0.60 — 0.51	4.0 — 4.9
18	— 0.70 — 0.61	3.0 — 3.9
19	— 0.80 — 0.71	2.0 — 2.9
20	— 0.90 — 0.81	1.0 — 1.9
21	— 1.00 — 0.91	0.0 — 0.9

falling in this range are 67.8, 61.7, and 50.0 percent.

At the extremes of the range, 4.6 percent of group I, 6.3 percent of group II, and 11.1 percent of group III evaluated three-fourths or more of the statements correctly; evaluating less than one-fourth correctly were 2.3 percent of group I, 1.4 percent of group II, and 4.5 percent of group III.

Despite these variations, none of the distribution of indices was significantly different at the 0.05 level; only those for groups I and II approached being significantly different. While the data did not support the hypothesis with respect to ground water, the respondents in the low status group had a larger proportion of indices reflecting correct evaluation of one-half or more of the statements than did either of the other two status groups (Table 1).

The mean information indices, on the other hand, indicated a higher knowledge score for the high status group. For status groups I, II, and III, the mean indices were 10.00, 9.49, and 9.06. They clustered at and near the half-correct/half-incorrect relationship and while the differences

were not statistically significant, the difference between group I and group III approached significance (Table 2).

The major implications of the data are twofold. First, despite contradictory indications with respect to support of the hypothesis being examined, the status groups are not significantly different with respect to their general knowledge about pollution and supply of ground water. Second, in general, respondents appear to be more uninformed than informed with respect to pollution and supply of ground water.

Table 1. Distributions of Ground Water Information Indices, Household Heads Classified by Status Groups; Selected Census Tracts, Warwick, Rhode Island (1969)

Range of Information Indices	Status Groups I No.	I %	II No.	II %	III No.	III %	Total No.	Total %
15.0-20.0	4	4.6	13	6.3	10	11.1	27	7.0
10.0-14.9	22	25.3	63	30.6	31	34.4	116	30.3
5.9- 9.9	59	67.8	127	61.7	45	50.0	231	60.3
0.0- 4.9	2	2.3	3	1.4	4	4.5	9	2.4
Total	87	100.0	206	100.0	90	100.0	383	100.0

Groups	X^2	df	P	
I, II, III	9.09	6	>0.05	
I, II	1.54	3	>0.05	
II, III	5.97	3	>0.05	
I, III	6.62	3	>0.05	(=0.0882)

Table 2. Significance of Differences Between Mean Ground Water Information Indices for Status Groups: Differences, X/0, and P for Status Groups; Household Heads Classified by Status Groups; Selected Census Tracts, Warwick, Rhode Island (1969)

Status Groups	Differences Between Means	X/O	P
I and II	0.51	1.1116	0.2670
II and III	0.43	0.9018	0.3682
I and III	0.94	1.6480	0.0990

Mean ground water information indices for status groups:
I: 10.00; II: 9.49; III: 9.06. All households 9.50.

Surface Water (Exposed Bodies of Fresh Water). As was the case with knowledge about pollution and supply of ground water, so with surface water. The data analyzed did not show statistically significant differences

among the status groups. This held both for distributions of information indices and for the mean indices for each status group. There is also indication that respondents lacked information about surface water pollution and supply; more than one-half of the respondents evaluated less than one-half of the statements correctly. Among all respondents, 57.7 percent evaluated between one-fourth and one-half of the statements correctly. For status groups I, II, and III, the percentages falling in this range were 55.2, 59.2, and 56.7 percent.

At the extremes of the range, 2.3 percent of group I, 1.0 percent of group II, and 2.2 percent of group III evaluated three-fourths or more of the statements correctly; evaluating less than one-fourth correctly were only 2.2 percent of group III.

None of the distributions of indices for the status groups was significantly different at the 0.05 level. Yet, the differences among the status groups did provide some support for the hypothesis with respect to surface water. Status group I, with high status, has the smallest percentage of respondents (55.25) evaluating less than one-half of the statements correctly and the largest percentage (44.8) evaluating more than one-half correctly. The largest percentage for the former and the smallest for the latter are in status group II, which gives group III, with low status, an intermediate position with respect to knowledgeability. Thus, there was some support for the hypothesis, but the relationship of association between knowledge and status did not hold consistently throughout the status groups (Table 3).

The mean information indices for surface water showed the same kind of relationship as for ground water. For status groups I, II, and III, the mean indices were 9.31, 9.28, and 9.19 percent. The means clustered near the half-correct/half-incorrect relationship and were not significantly different (Table 4). There is a slight indication that all respondents were less informed about surface water than about ground water.

The evidence, then, indicates that the status groups were not significantly different with respect to their general knowledge about pollution and supply of surface water, although the high status group were slightly better informed. However, respondents appear to be more uninformed than informed with respect to surface water.

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Table 3. Distributions of Surface Water Information Indices; Household Heads Classified by Status Groups; Selected Census Tracts, Warwick, Rhode Island (1969)

Range of Information Indices	Status Groups I No.	I %	II No.	II %	III No.	III %	Total No.	Total %
15.0-20.0	2	2.3	2	1.0	2	2.2	6	1.6
10.0-14.9	37	42.5	82	39.8	35	38.9	154	40.2
5.0- 9.9	48	55.2	122	59.2	51	56.7	221	57.7
0.0- 4.9	0	0.0	0	0.0	2	2.2	2	0.5
Total	87	100.0	206	100.0	90	100.0	383	100.0

Groups	X^2	df	P
I, II, III	7.90	6	>0.05
I, II	1.07	3	>0.05
II, III	5.39	3	>0.05
I, III	2.09	3	>0.05

Table 4. Significance of Differences Between Mean Surface Water Information Indices for Status Groups: Differences, X/o, and P for Status Groups; Household Heads Classified by Status Groups; Selected Census Tracts, Warwick, Rhode Island (1969)

Status Groups	Differences Between Means	X/O	P
I and II	0.03	0.1056	0.9124
II and III	0.09	0.2962	0.7718
I and III	0.12	0.2936	0.7718

Mean surface water information indices for status groups:
I: 9.31; II: 9.28; III: 9.19. All households 9.27.

SUMMARY

In general, analysis of the mailed questionnaire used in this study showed a slightly larger proportion of the respondents in the uninformed category with respect to knowledge about both surface water and ground water. Some differences in knowledge existed among the three status groups, but none of the differences was significantly different.

The findings in this study suggest that a greater understanding of water supply and pollution control is needed if "rational" decisions are to be made. This is particularly true in states such as Rhode Island where an approval of the voters at a public referendum is necessary to obtain development funds. The general lack of knowledge about water may be the result of the attitude that water, like air, is a free resource.

ECONOMIC JUSTIFICATION FOR GROUND WATER POLLUTION CONTROL

Arthur D. Jeffrey[1]

Withdrawal use of ground water in the State of Rhode Island has been minimal. The estimated current withdrawal of ground water of about 45 million gallons per day (mgd) represents but 20 percent of the estimated pumping capacity in the state. The pumping capacity is not the total amount of ground water available, but is defined as an estimate of the ground water that would be available if the low flow in the streams and rivers is to be maintained.

GROUND WATER IN THE UPPER PAWCATUCK RIVER BASIN

This study is concerned with only one area of the State of Rhode Island, the Upper Pawcatuck River Basin. This river basin is located in the southcentral part of the state. It includes a major portion of the town of South Kingstown, and also parts of Exeter, West Greenwich, Richmond, and small portions of North Kingstown, Charlestown, and East Greenwich.

Although ground water may be obtained almost anywhere in the basin, two areas in particular will yield substantial amounts. One extends from approximately the vicinity of Ladd School in Exeter to about a mile south of the village of Usquepaugh. This reservoir is referred to as the Usquepaugh-Queen ground water reservoir. The smaller reservoir area extends from the vicinity of Hundred Acre Pond to Larkin Pond and is known as the Chipuxet ground water reservoir. The combined potential rate of withdrawal of the two reservoirs was estimated to be about 25 mgd by the U. S. Geological Survey.[2]

Ground Water Use in The Basin. At the present time, the entire supply of water for all uses in the Upper Pawcatuck River Basin and the immediate towns and villages adjacent to the basin comes from the ground. In addition to the large number of individual well users found throughout the basin, there are three water systems that sell water to others located both in the basin itself and adjacent to it and two institutions that have their own ground water supply wells. In total this amounted to only

1. Professor of Economic Development and Regional Planning, University of Rhode Island. This study was based in part on an unpublished thesis by Arnold J. Antak, "Some Economic Planning Considerations of Ground Water Pollution for the Upper Pawcatuck River Basin in Rhode Island," 1970.

2. Allen, William B., Glenn W. Hahn, and Richard A. Braikley, Availibility of Gound Water, Upper Pawcatuck River Basin, Rhode Island, Geological Survey Water-Supply Paper 1821, 1966.

1.83 mgd out of the estimated dependable yield of 25.6 mgd. Additionally, most of the present withdrawal does not tap the two major ground water reservoirs. Table 1 indicates these water systems and their demands in 1965.

As the communities located within and adjacent to the Upper Pawcatuck River Basin develop and grow, the demand for potable water will undoubtedly increase. The fact that a large ground water supply underlies the area means that any plans for future development must give careful consideration to this valuable resource.

Water Quality Analysis. During the summer of 1969, the results of private wells tested in the towns of South Kingstown and Exeter during the year 1968 and up to September 1969 were obtained from the Rhode Island Department of Health. In addition, the results of tests on public ground water supplies were analyzed. The findings from these analyses indicated that areawide pollution of the ground water supply of the Upper Pawcatuck River Basin does not exist at the present time. The fact that most of the basin is rural and sparsely developed has prevented the occurrence of a widespread ground water pollution problem. However, a serious ground water pollution problem may occur in the basin as future development of the area takes place, if the present means of disposing of sewage continues into the future.

Table 1. Water Systems in the Upper Pawcatuck River Basin and Demands (1965)

Water System	People Served	Yield Capacity (mgd)	Average Daily Demand in 1965 (mgd)
Wakefield Water Company	8,500	5.0	1.0
Narragansett	2,200	Water purchased from Wakefield Water Company	0.22
Kingston Fire District	1,300	0.60	0.05
Ladd School	1,000	0.20	0.20
University of Rhode Island	4,600	1.9	0.36
Total	17,600		1.83

Source: Preliminary Plan for Public Water Supply and Distribution, Ground Water Reservoirs of the Kingston Quadrangle, Rhode Island.

There are several reasons why an area-wide ground water pollution problem could occur in the future. First, the northern portion of the basin has till as its principal unconsolidated deposit. Since till consists of fragments ranging in size from clay particles to boulders, pollutants introduced into this material are likely to travel much greater dis-

tances than those introduced into the outwash deposits. Since pollutants travel farthest in the direction of ground water flow, the danger of polluting the ground water reservoirs in the central part of the basin exists due to the movement of ground water from north to south.

A second reason why a serious ground water pollution problem may occur as development increases in the future is the fact that throughout most of the basin, the depth to the ground water is relatively shallow. Generally, the water table is within ten feet of the land surface. The existence of a high water table allows little time for sewage effluent to percolate through the zone of aeration where maximum purification of water occurs. In addition, movement of pollutants is generally much greater just below the water table, where most pollutants occur, than at greater depths.

The majority of the private wells in the basin are dug wells. These wells are especially susceptible to contamination because of their large diameter and the associated difficulties in sealing them properly from surface contaminants such as polluted water, sewage, rubbish, and decaying vegetation. If dug wells continue to be a common means of obtaining water for private use, then the danger of the water in these wells becoming polluted will continue to be a major concern throughout the basin.[3]

Finally, evidence exists to support the contention that the soil characteristics in much of the area of the Upper Pawcatuck River Basin may be unsuitable for private sewage disposal facilities. The need for public sewage facilities in the highly developed adjoining communities of Wakefield and Peace Dale has been recognized for many years. Also, the large percentage of individual wells that have shown the presence of various pollutants indicates that septic tanks may not be an acceptable means of sewage disposal, especially in areas where development becomes dense. As development takes place in the basin, the rate of pollution may very well be greater than the rate of population growth if private water supply and sewage disposal facilities are placed on lots too small to properly accommodate them.

THE PROBLEM

The most dangerous source of ground water pollution was found to be the sewage that enters the ground through the use of septic tank and cesspool disposal systems on individual lots. A means of eliminating this hazard would be the development of a municipal or regional sewage

3. In 1969 a total of 157 private wells were tested by the Rhode Island Department of Health. Of these, only 76 were reported as being completely free of all contamination. At that time, however, only 14 of these samples were considered to be so unsafe for human consumption that another source of supply should be sought.

treatment and disposal system. It was hypothesized that savings can accrue to the Upper Pawcatuck River Basin region in the long run through the development of the ground water reservoirs found in the basin, together with a regional sewage treatment and disposal system to eliminate the sewage that is presently being disposed of below ground. These savings would occur as a result of eliminating the development costs associated with a surface water supply that would be necessary if the present ground water supply should become polluted.

The Need for Centralized Supply and Disposal Systems. In suburban areas where municipal facilities are lacking, the construction of homes requires that water supply and sewage disposal facilities be developed on the same lot. However, the placement of these on a small home lot represents conflicting uses of the land. From the well data analyzed in this study, it was found that many individuals' water supplies in the Upper Pawcatuck River Basin have been harmed due to the improper placement and/or functioning of the sewage disposal system and/or well.

From an economic point of view, individual disposal systems are not the most efficient means of disposing of sewage. Not only are the initial installation costs generally higher than the cost to connect to a central system, but also the maintenance costs for septic tank disposal systems are from 40 dollars to 100 dollars higher per year than the normal sewer use charges of a central system.

Furthermore, even under perfect conditions, the disposal of sewage by means of individual septic tank systems is a temporary measure. Not only will the septic tank disposal system fail in the long run functionally, but also those areas where development becomes dense will eventually require the abandonment of private sewage disposal facilities and connection with a municipal or regional sewage treatment and disposal system.

The use of on-lot water supply and sewage disposal systems may have an effect on the pattern of land development and land cost. Individual disposal systems demand an area of considerably larger dimensions than the typical house lot connected to a public sewerage system in order to provide for an acceptable absorption field. This has produced the need for providing a suburban home lot about three times larger than the typical suburban lot where a control disposal system exists. Thus, suburban developments have often resulted in the inefficient use of large amounts of land.

If the market demand for land in a particular area is large, the price of land will reflect the need of using a large portion of the lot for sewage disposal purposes. Other improvements such as streets, also

mean a higher cost, since a development with large lots will require greater frontage for streets. Furthermore, when the development eventually connects to a municipal system, the unamortized portion of the cost of septic tank installation is lost, since the lines are usually in the rear yard and cannot be converted.

Likewise, central water supply is generally more desirable than individual wells where future development is envisioned. As suburban areas have been built up, individual wells have become less dependable as to the quantity and quality of water supplied. The inclination in the suburbs has been to ignore the development of central water supply and sewage disposal facilities until the individual systems have proven to be inadequate and a serious well pollution problem has occurred.

The development of a large scale municipal well system in the Upper Pawcatuck River Basin can be advocated for several reasons:

1. Well water developments on individual lots are a short run method of providing an adequate supply of water. As further development takes place, some areas of the basin may not be capable of yielding a sufficient quantity of water, e.g. areas underlain by bedrock.

2. There exist two extensive ground water reservoirs in the central part of the Upper Pawcatuck River Basin that are capable of supplying water not only to the communities in the basin itself, but also to surrounding areas.

3. A municipal water supply system could be a tool for planning the future development of the basin by providing water to particular areas where development is desired.

COST COMPARISONS

In 1968, Charles A. Maguire and Associates of Providence prepared a report for the town of Narragansett proposing waste water collection and disposal facilities when it was found that the existing public sewage treatment and disposal facilities did not meet the general needs of the state to preserve the shoreline and reduce pollution. In the report, joint facilities with the town of South Kingstown and the University of Rhode Island were recommended.

In June 1969, a plan was approved for the development of a combined sewage treatment plant and outfall system that would initially serve the town of Narragansett; the villages of Wakefield, Peace Dale, and Kingston in the town of South Kingstown; and the University of Rhode Island. The development cost of this system, excluding lateral lines, was estimated in 1968 to be $2,500,000. The cost given in 1968 dollars was updated to 1969 dollars and amounted to $3,040,000. (Table 2).

In 1965, Paul R. Farragut estimated the cost of developing the ground water reservoirs in the Upper Pawcatuck River Basin using information obtained from the R. E. Chapman Compan , the U. S. Geological Survey, and the Kent County Water Authority. The total development cost of the 25 mgd well development in 1965 was estimated to be $3,824,256. This figure was undated to reflect 1969 prices and was estimated to be $4,489,107.

Table 2. Updated System Cost Itemization, (Combined Sewage Treatment and Disposal System for Narragansett, South Kingstown, and the University of Rhode Island)

Item	July 1968 Prices	Cost October 1969 Prices
1. Primary sewage treatment plant designed for 1995 flows—exclusive of site acquisition	$1,800,000	$2,200,000
2. 24-inch sewer from force main to treatment plant to marine outfall—designed for 2020 flows	180,000	220,000
3. 24-inch cast iron marine outfall 1,350 foot long designed for 2020 flows	200,000	230,000
4. Other project costs*	320,000	390,000
Total development cost	$2,500,000	$3,040,000

*Other costs include site acquisition for pump station and treatment plant, engineering, supervision of construction, and project contingency.
Source: Charles A. Maguire and Associates and Indexes from Engineering News-Record.

Data for the proposed Big River surface reservoir were used in this study since the dependable yield was approximately the same (26 mgd) as that of the Upper Pawcatuck River Basin well development. Using information from a report by Metcalf and Eddy Engineers of Boston, the cost of developing the surface reservoir in 1967 prices was approximately $11,592,000. This figure was updated to reflect 1969 prices and the development cost of the surface reservoir was estimated to be $13,612,800. Thus, the total development cost of the Upper Pawcatuck River Basin ground water supply was approximately 4.6 million dollars while the total development cost of the Big River surface supply was approximately 13.6 million dollars, with both supplies yielding about the same amount of water (Table 3).

The largest variation in the cost of the individual items in the development of the ground water or surface water supply appeared in the

"land acquisition" item. Although the cost of land necessary for the ground water development was liberally estimated at $72,000 for 30 acres, the total cost of land for the surface water supply amounted to $4,300,000 or $4,228,000 more than the land cost for the ground water development. This was due to the fact that the surface water supply required 8600 acres, while the ground water development required only 30 acres of land.

Since the costs of all the systems considered had been updated, the hypothesis could be tested. Development costs for the various systems are the following:

Sewage Treatment and Disposal System	$ 3,040,000
Upper Pawcatuck Ground Water Development	$ 4,589,107
Big River Surface Reservoir	$13,612,800

Table 3. Cost Comparison Between Development Costs of the Upper Pawcatuck River Bason Ground Water Supply and the Big River Reservoir Surface Supply (1969 prices)

Upper Pawcatuck Yield 25 mgd		Big River Yield 26 mgd	
Item	Cost	Item	Cost
Land	$ 72,000	Land	$4,300,000
Pipeline between wells	72,000	Clearing and grubbing	1,840,000
Test wells	96,000	Demolition of structures	92,000
Supply wells, pump, and well houses	1,800,000	Cemetery relocation	79,000
Pipe from wells to standpipe	1,796,256	Highway relocation	1,700,000
Engineering and contingencies	752,851	Dams, dikes, and appurtenant works	3,070,000
		Public utility relocations	263,000
		Engineering and contingencies	2,268,800
Total development cost	$4,589,107	Total development cost	$13,612,800
Estimated initial cost of development per million gallons	$183,564	Estimated initial cost of development per million gallons	$516,000

The combined total development cost for the ground water development and sewage treatment and disposal system was $7,629,107, while the cost of developing the surface water reservoir amounted to $13,612,800. Thus, the cost of the surface water development was $5,983,693 greater than the development cost of the ground water supply and sewage treatment and disposal system combined. The development of the ground water supply and sewage treatment and disposal system represents a 40 percent saving over the cost of developing a surface water supply that would yield approximately the same amount of water.

Some Additional Cost Considerations. This study has been concerned with two alternative methods of providing a water supply. The development costs presented in this study included: (1) the purchase cost of acquiring the necessary amount of land for the particular project; (2) costs of supersession, which are the costs of removing any improvements, such as buildings, already located on the land; and (3) the construction cost of the new development.

Since the development of land usually involves the passing of some duration of time, there exist what are known as time costs which should be considered. Time costs include two types of costs that are associated with the holding of land. The first, waiting costs, are those costs which arise between the time of the first outlay of capital and labor and the time when the investment can be put to actual use. Interest charges would be considered a waiting cost.

In 1965, land was condemned by the state for the development of the Big River and Wood River Reservoirs. The state bought a total of 444 parcels of land. Two bond issues were necessary to finance land acquisition for the two reservoirs which totaled 7.5 million dollars. Most of this money was used for land acquisition for the Big River Reservoir.4 The interest rates for the 20-year straight serial bonds were as follows:

	Value (dollars)	Rate (percent)	Amount (dollars)
	1 million	3.375	337,500
	3 million	3.850	1,115,000
	1 million	4.500	450,000
	2.3 million	4.050	931,000
Total	7.3 million		2,833,500

4. Most of the land for the Big River Reservoir has now been purchased by the state. The comparative study was based on cost estimates prior to actual purchase. While the purchase price of a few parcels is still unsettled, the figure of 7.3 million dollars for land acquisition appears to be reasonable in light of present information.

Thus, over the 20-year period over 2.8 million additional dollars will be expended in waiting costs for the purchase of land necessary for the Big River Reservoir. Since the amount of land needed for the ground water system is negligible by comparison, this additional cost must be borne by the surface system.

The second time cost is what is known as ripening costs. Ripening costs consist of the carrying costs that are incurred until the land is put to the new use. The loss of tax revenue would be classified a ripening cost.

In the case of the Big River Surface Reservoir, the state must make payments to the town of West Greenwich in lieu of property taxes for 25 years. The state must pay the amount that West Greenwich received in taxes on the land assessed as of December 31, 1963. The payment is reduced 4 percent each year for 25 years. The entire reimbursement will equal $382,550. This $382,550 represents a ripening cost associated with the Big River Reservoir development. The fact that the ground water system could be developed as needed by drilling additional wells, while the surface system must be developed all at once, means that the ground water system has an additional economic advantage over the surface system when waiting and ripening costs are considered.

SUMMARY AND CONCLUSIONS

An economic justification for pollution control has usually been difficult to establish. Since the development of surface reservoirs is an expensive undertaking relative to the development of a ground water system, a condition that could be considered extreme in cost differences exists in at least one area of Rhode Island. This study found that the combined costs of developing a ground water system and a regional sewage treatment and disposal system were considerably less than the development costs of a surface impounding reservoir that would yield approximately the same amount of water.

The findings in this study suggest that planning for water supply and sewage disposal facilities should be done on a comprehensive basis. The economies that might be realized when both water supply and sewage disposal are treated as a single function is to be investigated.